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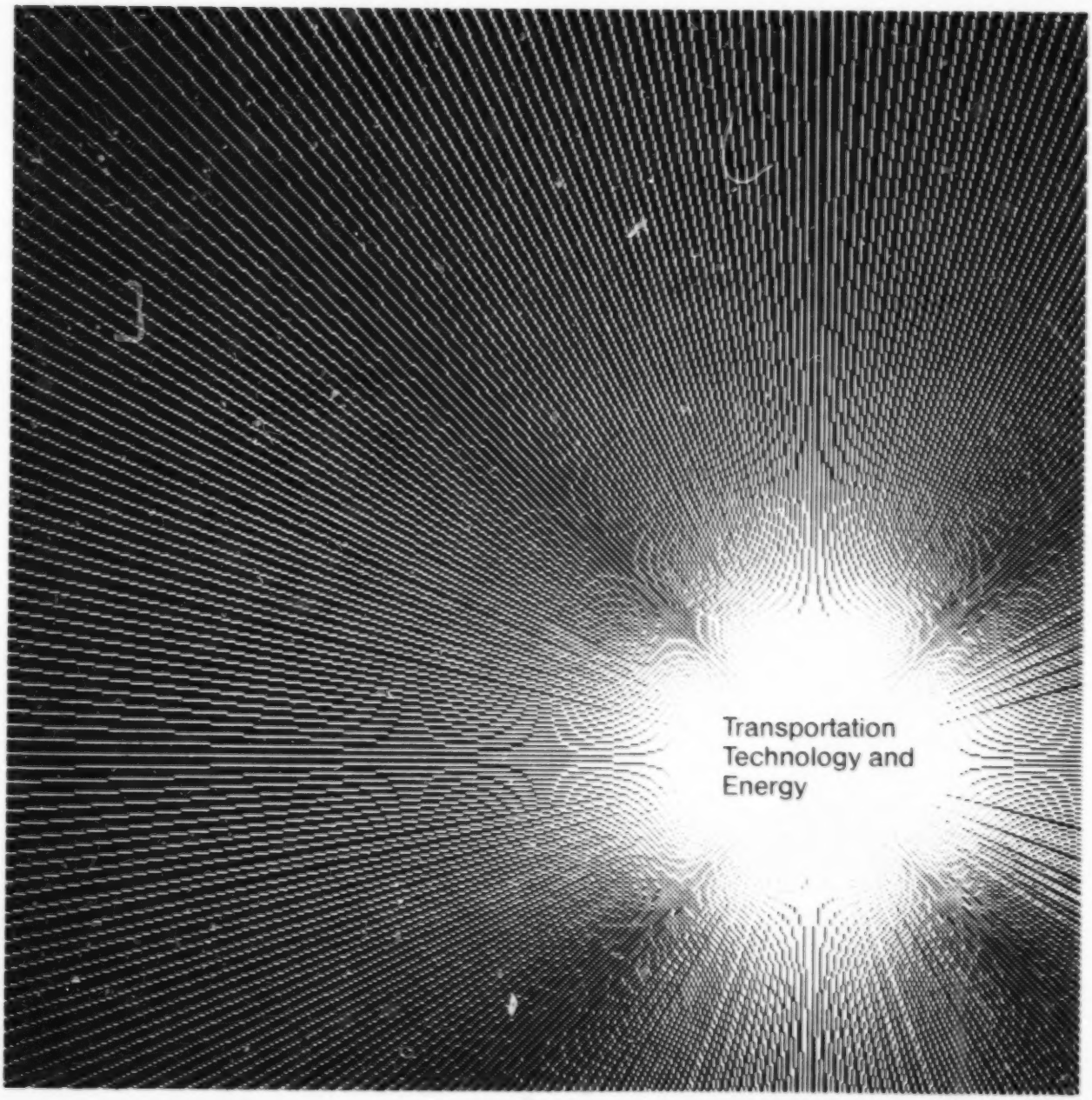
VS-84-01

Ride Quality of Ontario Northland Rail Car # 1987-A



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Ride Quality of Ontario Northland Rail Car #1987-A

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Prepared for
The Ontario Northland Transportation Commission

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EXECUTIVE SUMMARY

This report documents the ride quality of car #1987-A of ONTC'S "TEE-Train", measured over three different sections of ONR track. The three sections comprise one smooth tangent (113 km/h, 70 mph), one fair tangent (113 km/h, 70 mph), and one curve (64 km/h, 40 mph). Ride quality was measured in the vertical and lateral directions of the A-car, first in the forward end over the truck and then at the centre of the car. The train was run over each of the three sections of track at least six times -- three with the ride-measuring equipment forward and three with the equipment at the centre.

In addition to the ride meters, four accelerometers were mounted in various positions and orientations in the car to provide supplementary ride information including roll and yaw characteristics.

A radar speed detector was mounted on the outside of the car to monitor train speed but ice accumulation on the transmitter/receiver rendered the radar speed detector inoperative.

Electrical outputs from the ride meters and accelerometers were recorded on paper and magnetic tape for laboratory analysis. This report deals only with the ride measurements recorded from the two ride meters. Another report will be issued at a later date containing a more detailed analysis of the ride meter and accelerometer data in defining the overall ride characteristics of the car/track combination.

The results may be briefly summarized as follows:

- Speeds of 59 to 64 km/h (37 to 40 mph) on curved track resulted in average ride indices of under 2.0 vertical, and 2.2 to 2.6 lateral.

- Speeds of 105 to 113 km/h (65 to 70 mph) on smooth tangent track resulted in average ride indices of 2.4 to 2.65 vertical, and 2.4 to 2.5 lateral.

- Speeds of 80 to 97 km/h (50 to 60 mph) on rough tangent track resulted in average ride indices of 2.2 to 2.6 vertical, and 2.55 to 2.8 lateral.

The above levels correspond to a qualitative ride quality of between "satisfactory" and "good" according to Table 6.

The above information may be used as a guide in comparing the TEE-Train to equipment operated by other agencies, or as an aid in the purchase of new equipment. The figures should not, however, be quoted directly in specifications for new equipment because of the important role that track condition plays in absolute ride quality.

1/ INTRODUCTION

The Ontario Northland Transportation Commission (ONTC) currently provides daily passenger train service between Toronto and the northern Ontario cities of Kapuskasing and Timmins. The "Northlander" service operates on the Toronto-Timmins route, one train each day from each city, using equipment formerly employed on the famous Trans-European Express trains (TEE-Trains). On the Toronto-Kapuskasing service, which ONTC calls "The Northland", the Commission uses trains of domestic design. One "Northland" train each day leaves Toronto and Kapuskasing.

The domestic Northland is the older of the two train types and ONTC is currently investigating their replacement with new equipment. In order to ensure that new equipment, if purchased, gives the same quality of ride as the TEE-Train (or better), ONTC asked to have the ride quality of the TEE-Train measured using standard British Rail (B.R.) ride meters. Assistance was provided by the Transportation Technology and Energy Branch which arranged a preliminary test of the vehicles' ride characteristics. This report describes the test procedure and the ride level data obtained.

Because the track has a large influence on the ride quality, three sections of track north of North Bay were identified by ONTC which would be somewhat representative of the variety of track conditions and geometry on the above-mentioned runs. The three sections comprise representative examples of:

- good tangent track,
- fair tangent track, and
- a smooth curve

to study the effects of track condition and geometry on ride for a given vehicle.

2/ OBJECTIVES

The objective of the test was to quantify the ride characteristics of the TEE-Train over three different sections of track. At present, this information is just for the information of the ONTC. However, it may, at some later date, be considered in the evaluation of new equipment or for the writing of a ride quality specification for new equipment.

3/ TESTING AND DATA ANALYSIS

The car selected for testing was car A of ONR's TEE-Train #1987. It was the first car of the consist and considered to be typical of its type.

Although a large amount of accelerometer information was recorded in addition to the ride meter levels, it has not been considered in this report. Rather, a more detailed study of this information will be undertaken and reported on to provide further insight into the trains' ride characteristics. This further report will be issued at a later date.

3.1/ Test Sections

The three selected test sections are all within 74 km (46 miles) of the ONTC yard in North Bay (test locations are mapped in Figure 1). The test track sections were selected to yield three different ride quality levels.

Details of the three test sections are as follows:

1/ **Curved** -- The curved section consists of a two-mile stretch (from mile post 23 to 25) incorporating six individual curves. The grade on this section is -1%. The track characteristics with respect to curve length, radius and superelevation are given in Appendix A. Speed through this section is limited to 64 to 72 km/h (40-45 mph).

2/ **Straight, Good** -- This section is a two-mile stretch of continuously welded track from mile post 37 to 39. Typical speeds on this run are 97 to 113 km/h (60 to 70 mph). The grade on this section is +0.24%.

3/ **Straight, Fair** -- The last section is one mile long from mile post 45 to 46 and is comprised of jointed tracks. (This is one of the least smooth sections on the ONR System). Typical speeds are 97 to 113 km/h (60 to 70 mph) and the grade is +0.27%.

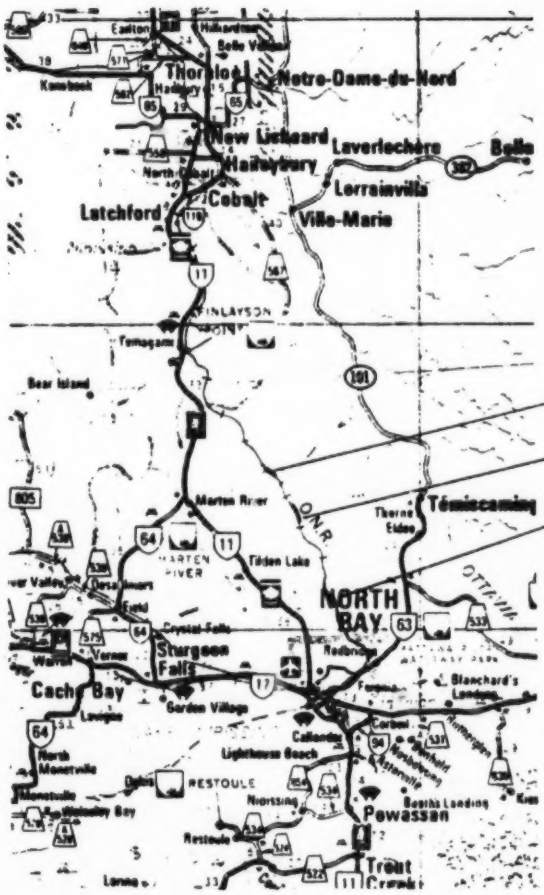

Figure 1/ Test Locations on ONR Track

3.2/ Instrumentation

3.2.1/ Transducers

There were two different types of measurements made on the car floor. These were acceleration, and ride index.

The transducer used for measuring acceleration was the Bruel & Kjaer Uni-Gain accelerometer, type 8306.

The ride index was measured by the Data Acquisition Limited vehicle ridemeter, MKII version.

3.2.2/ Test Equipment

The major equipment used is listed in Table 1, below.

Table 1/ Equipment

Item	Equipment
1.	On-board 220 Vac, 50 Hz power supply.
2.	Hewlett-Packard Model 6269-B dc power supply.
3.	Honeywell Model DA 12-A electric generator.
4.	Metraplex 300 series signal conditioning/FM data acquisition system.
5.	Nagra Model IV-S instrumentation recorder.
6.	MFE Model 1800 eight-channel chart recorder.

3.2.3/ Installation of Transducers

The installation of transducers was very simple. Each transducer was placed on the car floor at its predetermined position. For each test rail section two sets of transducer set-ups were used. Figure 2 shows the first set-up which was referred to as Position 1.

Figure 3 shows the second set-up, referred to as Position 2.

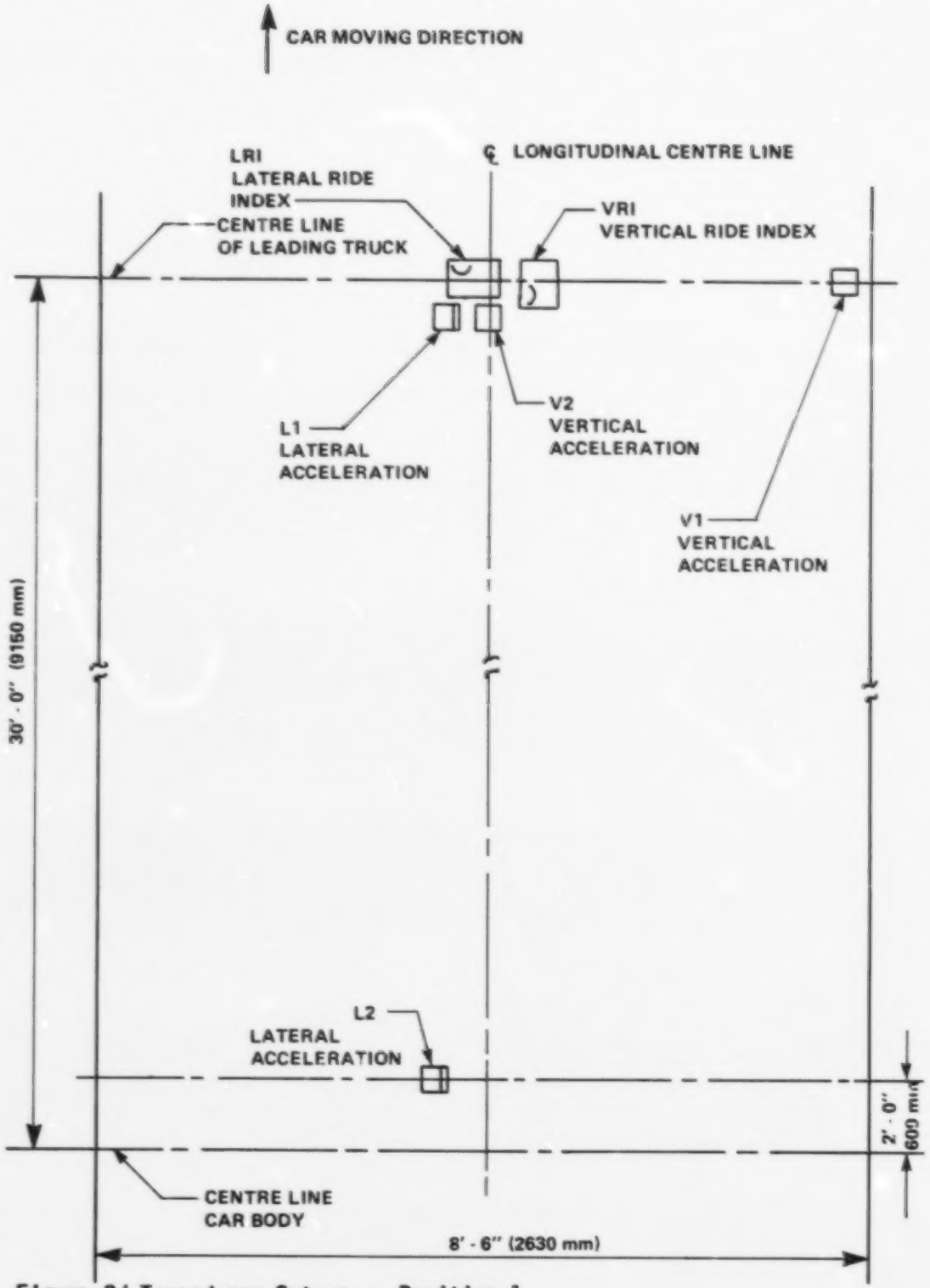

Figure 2/ Transducer Set-up -- Position 1

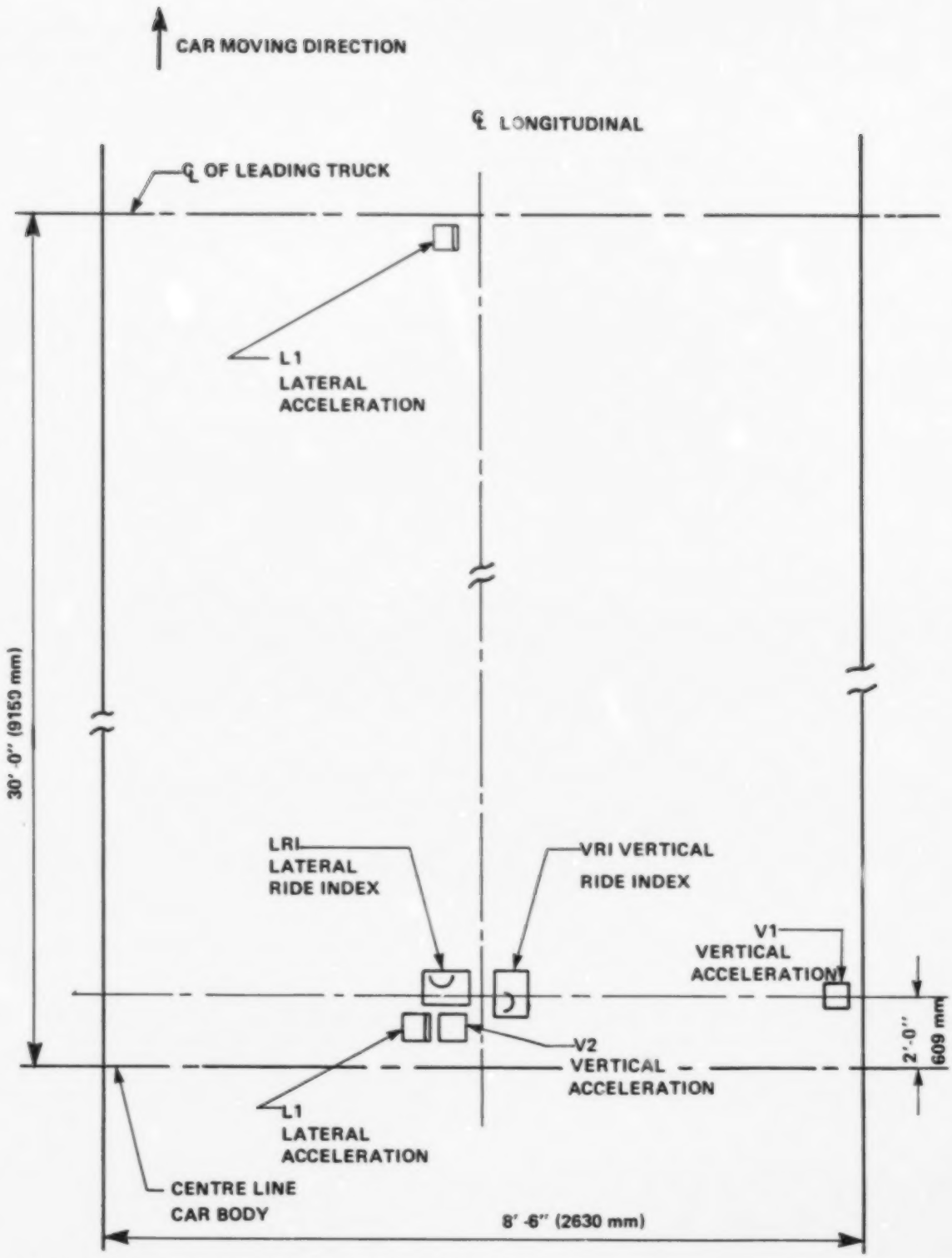

Figure 3/ Transducer Set-up -- Position 2

3.3/ Data Acquisition

3.3.1/ FM Data Acquisition

The channel allocations for the Nagra IV-S instrumentation tape recorder for the test locations (Positions 1 and 2) are listed in Tables 2 and 3, respectively.

Table 2/ Tape Recorder Channel Allocations for Position 1

Track	Channel	Parameter	
1	1	V1	Vertical acceleration on car floor at the car edge on the centreline of the leading truck.
	2	V2	Vertical acceleration on car floor at the centre of the leading truck.
	3	L1	Lateral acceleration on car floor at the centre of the leading truck.
	4	L2	Lateral acceleration on car floor at a location about 0.6 m (2 ft) forward of the centre of the car body.
	5	LRI	Lateral ride index on car floor at the centre of the leading truck.
	6	VRI	Vertical ride index on car floor at the centre of the leading truck.
2		IRIG	'B' Time Code.

Table 3/ Tape Recorder Channel Allocations for Position 2

Track	Channel		Parameter
1	1	V1	Vertical acceleration on car floor at the car edge and about 0.6 m (2 ft) forward of the centreline of the car body.
	2	V2	Vertical acceleration on car floor at the location about 0.6 m (2 ft) forward of the centre of the car body.
	3	L1	Lateral acceleration on car floor at the centre of the leading truck.
	4	L2	Lateral acceleration on car floor at a location about 0.6 m (2 ft) forward of the centre of the car body.
	5	LRI	Lateral ride index on car floor at the location about 0.6 m (2 ft) forward of the centre of the car body.
	6	VRI	Vertical ride index on car floor at the location about 0.6 m (2 ft) forward of the centre of the car body.
2		IRIG	'B' Time Code.

3.3.2/ Chart Recording

During the data recording, a hard copy of the corresponding real-time FM data recording was produced. The time history chart record was used both to monitor the data acquisition and to provide access for data analysis.

Figure 4 shows the scale factors of the chart recordings and channel allocations. A few copies of the chart recordings are attached, in Appendix B.

Figure 5 shows the time code interpretation.

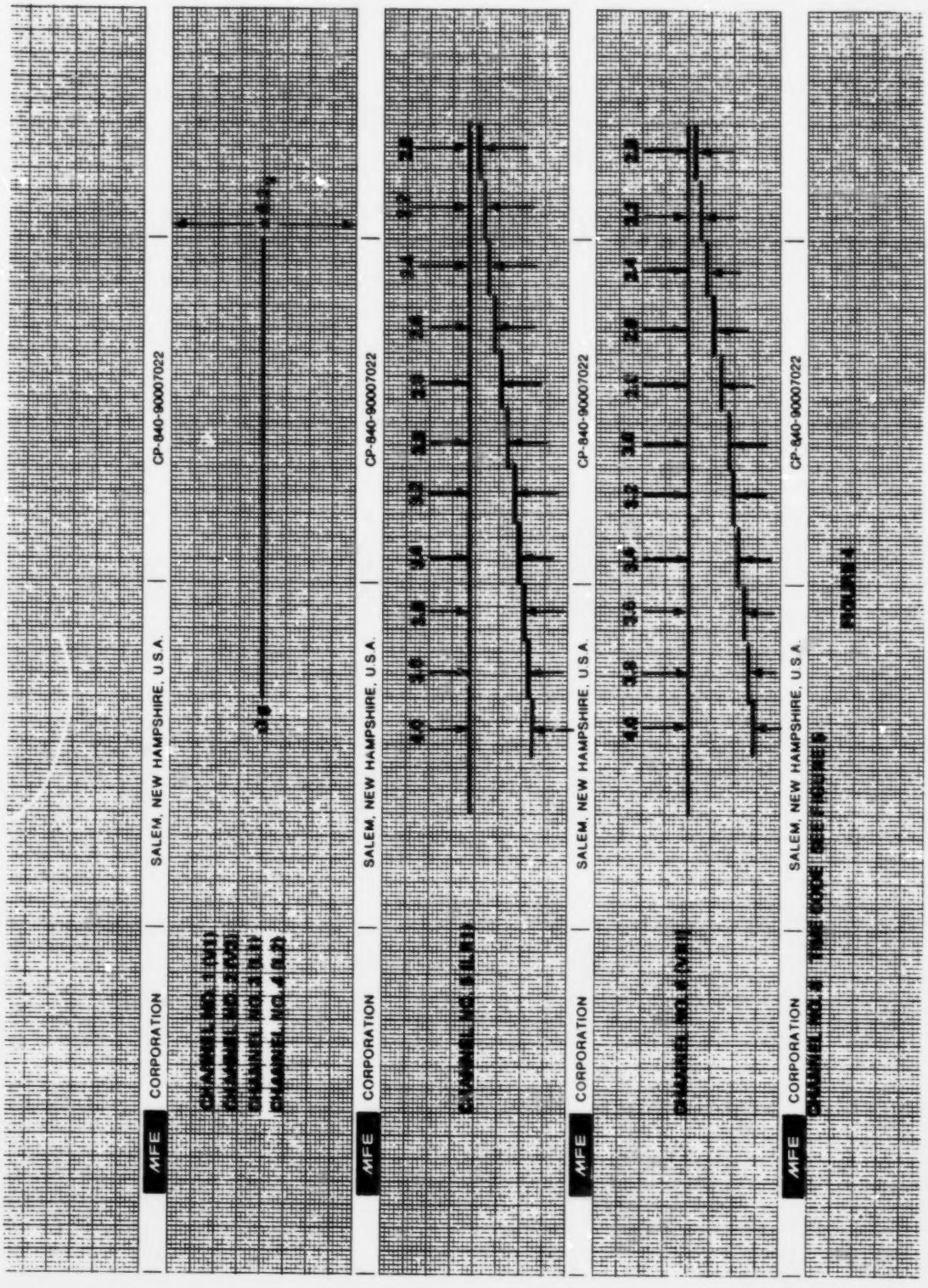

Figure 4/ Chart Recorder Scale Factors and Channel Allocations

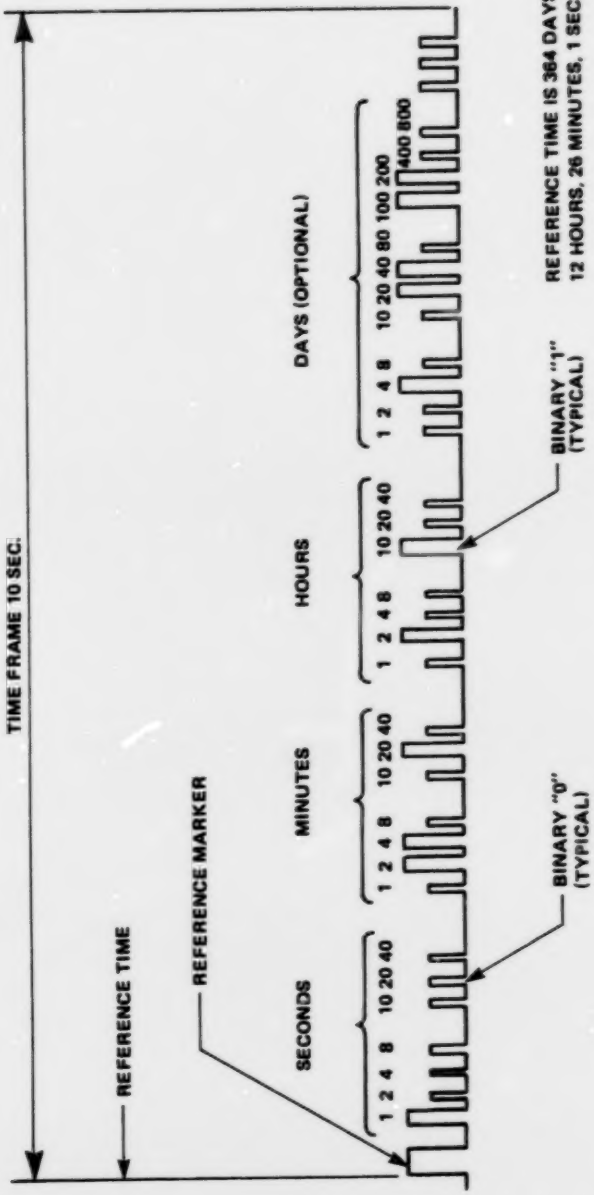
TIME FRAME 10 SEC.
REFERENCE TIME
REFERENCE MARKER
SECONDS
MINUTES
HOURS
DAYS (OPTIONAL)
1 2 4 8 10 20 40
1 2 4 8 10 20 40
1 2 4 8 10 20 40
1 2 4 8 10 20 40 80 100 200 400 800
BINARY "0" (TYPICAL)
BINARY "1" (TYPICAL)
REFERENCE TIME IS 364 DAYS 12 HOURS, 26 MINUTES, 1 SECOND

Figure 5/ Time Code

3.4/ Test Procedure

As mentioned in Section 3.1, three rail sections were chosen to monitor ride qualities of car #1987-A. At each test rail section, three runs each were made for two sets of transducer positions. A total of 19 runs were successfully recorded. Table 4 shows the data log. The time expression DDD-HH-MM-SS corresponds to the number of the day of year 1983, hours, minutes, and seconds.

Table 4/ Data Log

Tape No.	Test Run	Test Rail Section	Transducer Location	Start Time (DDD-HH-MM-SS)	Stop Time (DDD-HH-MM-SS)	Car Speed (mph)
1	1	2	2	333-10-50-18	333-10-52-08	68
	2	2	2	333-11-01-07	333-11-02-46	65
	3	2	2	333-11-13-03	333-11-14-40	68
	1	2	1	333-12-01-50	333-12-03-28	70
	2	2	1	333-12-14-29	333-12-16-04	70
	3	2	1	333-12-26-50	333-12-28-24	70
2	1	3	1	333-12-50-00	333-12-51-00	50
	2	3	1	333-12-58-56	333-13-00-00	50
	3	3	1	333-13-07-53	333-13-08-41	60
	4	3	1	333-13-16-50	333-13-17-46	60
	1	3	2	333-13-25-42	333-13-26-36	62
	2	3	2	333-13-34-43	333-13-35-37	60
	3	3	2	333-14-04-23	333-14-05-18	60
	1	1	2	333-14-54-43	333-14-57-18	37
	2	1	2	333-15-15-07	333-15-17-42	45
	3	1	2	333-15-43-24	333-15-46-03	44
	1	1	1	333-15-52-59	333-15-54-55	45
	2	1	1	333-16-01-14	333-16-03-47	45
	3	1	1	333-16-10-10	333-16-12-42	45

3.5/ Data Analysis

For this report, only the two ride indices were analysed. The peak and average ride index values were measured from the charts. These measurements were expected to be accurate within 0.2. It should be understood that the peak value, in most cases, was recorded only once or twice and only for a fraction of a second. The average values are very close to readings taken manually during the test runs.

Table 5 gives a summary of the two ride indices for all test runs. The interpretation of ride index values is given in Table 6.

Table 5/ Summary of Ride Index Values Obtained

Test Rail Section	Ridemeter Location	Run No.	Car Speed (mph)	Lateral Ride Index		Vertical Ride Index	
				Peak	Average	Peak	Average
1	Centre of leading truck	1	45	3.2	2.6	2.2	Under 2
		2	45	3.4	2.4	2.0	Under 2
		3	45	3.6	2.6	2.3	Under 2
	Centre of car	1	37	2.7	2.2	2.0	Under 2
		2	45	2.8	2.3	2.4	Under 2
		3	44	3.1	2.4	2.4	Under 2
2	Centre of leading truck	1	70	2.6	2.4	2.9	2.55
		2	70	2.7	2.4	2.9	2.7
		3	70	3.2	2.4	3.0	2.65
	Centre of car	1	68	3.5	2.5	2.8	2.50
		2	65	3.7	2.4	2.8	2.40
		3	68	3.6	2.4	2.8	2.45
3	Centre of leading truck	1	50			2.9	2.6
		2	50			2.85	2.5
		3	60	4.5	2.7	2.9	2.6
		4	60	4.6	2.8	2.9	2.6
	Centre of car	1	62	3.0	2.7	2.8	2.45
		2	60	3.0	2.6	2.6	2.4
		3	60	3.1	2.55	2.4	2.2

Table 6/ Interpretation of Ride Index*

RIDE INDEX		QUALITY OF RIDE
1.0	--	Very good
1.5	--	Almost very good
2.0	--	Good
2.5	--	Almost good
3.0	--	Satisfactory
3.25	--	Satisfactory with limitations
3.5	--	Just satisfactory
4.0	--	Operable
4.5	--	Not operable
5.0	--	Dangerous

*Ref. Instruction Manual, Ridemeter MKII.

4/ DISCUSSION OF RESULTS

The previous section outlined the test results in the form of average and peak ride indices in the forward and centre part of the car over three separate track sections. These are summarized in Table 5.

A review of the summary sheets reveals several interesting relationships. First, the average vertical ride index appears to be a function of train speed. At 59 to 72 km/h (37-45 mph) over Section 1, the average vertical ride index (AVRI) remained under 2.0. Runs made over Sections 2 and 3 resulted in AVRIs of between 2.2 and 2.7 at speeds of between 80 and 113 km/h (50 and 70 mph). Differences in track quality seemed to have little affect on AVRI which varied from 2.4 to 2.7 over Section 2, and from 2.2 to 2.6 over Section 3. Section 2 had a good track quality rating (from maintenance records), whereas Section 3 was rated only fair.

Lateral ride appeared very susceptible to track quality. Average lateral ride index (ALRI) registered 2.4 to 2.5 over Section 2, and 2.55 to 2.8 over Section 3 -- even though the speeds over the better Section 2 were higher, ranging from 105 to 113 km/h (65-70 mph) compared with 80 to 97 km/h (50-60 mph) over Section 3. ALRI over Section 1 was in the same range as over Sections 2 and 3 since Section 1 consists of six separate curves which tended to offset the benefit of a lower average speed (59 to 72 km/h, 37 to 45 mph).

Position 1 (forward, over truck) ride indices were generally slightly higher than Position 2 (centre of car) indices. This may be explained by the limited amount of shock absorption afforded by the structure of the car. Since Position 1 is directly over the truck (the source of all vibration), the ride indices should be slightly higher than at Position 2 where the vibration has travelled half the length of the car to get there. Pitching and yawing motions of the car could also be responsible for the difference in ride quality. Detailed analyses of the acceleration signals will yield more information on the subject. Power spectral density analyses of the acceleration signals will reveal any resonances at high frequencies (i.e., above 8 Hz) which may be annoying to the passenger

(even though they may not contribute very much to the measured ride indices).

Overall, the average ride, both lateral and vertical falls within the 2.0 to 3.0 levels which correspond to a "satisfactory to good" ride quality according to Table 6 of this report.

5/ CONCLUSIONS

The ride of ONTC's TEE-Train has been characterized over three representative sections of ONR track. The results describe the ride as "satisfactory to good". This is consistent with subjective observations from the test crew, operators, and passengers on the train that the ride is in fact very satisfactory.

In addition, the absolute value of the ride indices were in agreement with the track condition and geometry -- higher speeds resulted in a lower quality ride, as did curved track compared to tangent.

The test results yield basic ride quality information which will be useful in comparing TEE-Train ride quality with equipment operated by other agencies, or in the specification of ride requirements should new equipment be purchased.

6/ RECOMMENDATIONS

1/ It is recommended that the ride index values quoted in this report not be used as absolute criteria in specifying new equipment but rather as a guide. Any evaluation of new equipment should be carried out on a comparative basis, with tests done on the same track, with the same test equipment and, preferably, on the same day.

2/ The acceleration signals should be processed to obtain power spectral densities, which yield considerable insight into the vibration. The ride meter data should also be processed further to obtain probability distribution curves.

3/ It is recommended that the GO-Transit bi-level car be tested on the ONR track and detailed analysis of the data be carried out before finalizing the ONR specifications for bi-level cars. In particular, the "dither" problem should be studied to determine its nature and extent. The data from the TEE-Train and bi-level tests may then be used to prepare ride-related specifications for the ONR bi-level cars.

ACKNOWLEDGEMENTS

The authors would like to thank the Toronto Transit Commission and Hawker-Siddeley for the use of their ride meters in this test. Thanks are also due to the management of the Ontario Northland Transportation Commission for supplying all support personnel and the test train which made this test possible.

Appendix A/ ONR Curved Track Characteristics from Mile Post 23 to 25

Mile Post (At centre of curve)	Degree of Curve (degrees and minutes)	Length of Circular Curve (feet)	Length of Spiral Curve (feet)	Following Length of Tangent (feet)	Height of Super-elevation (inches)
22.83	6 00 L	675	270	45	4
23.04	5 00 R	283	240	10	3.75
23.19	3 55 L	464	118	1021	3.25
23.55	6 10 R	449	185	980	4
23.92	1 02 R	579	170	1725	1
24.38	6 135 R	277	180	10	4
	6 04 L	500	180		
24.58	6 07 L	364	180	216	4.5
24.90	3 03 R	1171	180	962	2.5
25.25	1 00 R	597	60	703	2

Appendix B/ Chart Records

1/ Test Rail Sec.1, Meter Location 1

2/ Test Rail Sec.1, Meter Location 2

3/ Test Rail Sec.2, Meter Location 1

4/ Test Rail Sec.2, Meter Location 2

5/ Test Rail Sec.3, Meter Location 1

6/ Test Rail Sec.3, Meter Location 2